AFRL-AFOSR-UK-TR-2012-0014

The Energy Spectrum of Accelerated Electrons from Wave-plasma Interactions in the Ionosphere

Mike J. Kosch

Lancaster University
Physics Department
Bailrigg
Lancaster, United Kingdom LA1 4YB

EOARD Grant 10-3036

Report Date: June 2012

Final Report for 10 March 2010 to 31 December 2011

Air Force Research Laboratory
Air Force Office of Scientific Research
European Office of Aerospace Research and Development
Unit 4515 Box 14, APO AE 09421

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
29-06-2012	Final Report	10 March 2010 – 31 December 2011

4. TITLE AND SUBTITLE

The Energy Spectrum of Accelerated Electrons from Wave-plasma Interactions in the Ionosphere

5a. CONTRACT NUMBER

FA8655-10-1-3036

5b. GRANT NUMBER

Grant 10-3036

5c. PROGRAM ELEMENT NUMBER

61102F

6. AUTHOR(S)

Professor Michael J. Kosch

5d. PROJECT NUMBER

5d. TASK NUMBER

5e. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Lancaster University
Physics Department
Bailrigg
Lancaster, United Kingdom LA1 4WA

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
Unit 4515 BOX 14
APO AE 09421

10. SPONSOR/MONITOR'S ACRONYM(S)

AFRL/AFOSR/RSW (EOARD)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

AFRL-AFOSR-UK-TR-2012-0014

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution A: Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

A HAARP campaign was executed 1-15 April 2010. Dr. Bjorn Gustavsson attended from the UK with optical equipment from Sweden and the UK. Unfortunately, no useful data was obtained. It was therefore necessary to find the resources to repeat the campaign effort (see budget below). A HAARP campaign was executed 21 March – 5 April 2011. Dr. Bjorn Gustavsson (3/21 – 4/5) and Prof. Mike Kosch (3/21 – 3/25) attended from the UK with optical equipment from Sweden and the UK. Very good optical data was obtained at multiple wavelengths (427.8, 557.7, 630.0, 7320.0, 777.4 and 844.6 nm). However, the emissions were highly structured in space and time. This fact, and the lack of electron temperature data at HAARP, made data analysis difficult. It became necessary to develop a quantitative model of the pump-wave self-absorption in the ionospheric D-region (publication 1), a quantitative model of electron heating in the ionospheric F-region (publication 2) taking into account D-region absorption, and an empirical model of electron temperature and optical emission intensity enhancements (publication 3) as a function pump wave power. These tasks have been completed now (see publications 1-3) using the EISCAT facility with its incoherent scatter radar, so progress on the originally specified task at HAARP can now be made.

15. SUBJECT TERMS

EOARD, Space Environment, Space Weather, Ionosphere, Ionospheric Heating, Radio Frequency Plasmas

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18, NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			SCOTT DUDLEY, Lt Col, USAF
UNCLAS	UNCLAS	UNCLAS	SAR	5	**19b. TELEPHONE NUMBER** *(Include area code)* +44 (0)1895 616162

Performance Report

The energy spectrum of accelerated electrons from wave-plasma interactions in the ionosphere

Contract FA8655-10-1-3036

Prof. Mike Kosch (Lancaster University, UK)

Activities:

A HAARP campaign was executed 1-15 April 2010. Dr. Bjorn Gustavsson attended from the UK with optical equipment from Sweden and the UK. Unfortunately, no useful data was obtained. It was therefore necessary to find the resources to repeat the campaign effort (see budget below).

A HAARP campaign was executed 21 March – 5 April 2011. Dr. Bjorn Gustavsson (3/21 – 4/5) and Prof. Mike Kosch (3/21 – 3/25) attended from the UK with optical equipment from Sweden and the UK. Very good optical data was obtained at multiple wavelengths (427.8, 557.7, 630.0, 7320.0, 777.4 and 844.6 nm). However, the emissions were highly structured in space and time. This fact, and the lack of electron temperature data at HAARP, made data analysis difficult. It became necessary to develop a quantitative model of the pump-wave self-absorption in the ionospheric D-region (publication 1), a quantitative model of electron heating in the ionospheric F-region (publication 2) taking into account D-region absorption, and an empirical model of electron temperature and optical emission intensity enhancements (publication 3) as a function pump wave power. These tasks have been completed now (see publications 1-3) using the EISCAT facility with its incoherent scatter radar, so progress on the originally specified task at HAARP can now be made.

Publications:

1) A. Senior, M.T. Rietveld, F. Honary, W. Singer, and M.J. Kosch. Measurements and modelling of cosmic noise absorption changes due to radio heating of the D-region ionosphere. J. Geophys. Res.,116, A04310, doi:10.1029/2010JA016189, 2011.

2) A. Senior, M.T. Rietveld, T.K. Yeoman and M. J. Kosch. The dependence of F-region electron heating on HF radio pump power: measurements at EISCAT Tromso. J. Geophys. Res., 117, A04309, doi:10.1029/2011JA017267, 2012.

3) C. J. Bryers, M. J. Kosch, A. Senior, M. T. Rietveld and T. K. Yeoman. EISCAT observations of pump-enhanced plasma temperature and optical emission excitation rate as a function of power flux. Accepted J. Geophys. Res., doi:10.1029/2012JA017897, 2012.

Budget:

Purchases are round to the nearest Dollar, and an exchange rate of 1 GBP = 1.6 USD has been assumed.

Equipment:

Filters (427.8, 777.4 & 844.6 nm), field-widening mirror, and lens:	1,340-

HAARP campaigns:

2010 (1 person, including flights, accommodation, shipping and consumables):	4,638-
2011 (2 persons, including flights, rental car, accommodation, shipping and consumables):	9,482-

Total:	15,460-

The original budget ($8580-) was exceeded by $6880- and this was resourced from elsewhere.

Collaborations:

The HAARP activity supported by EOARD has resulted in multiple collaborations between US scientists and the EISCAT facility in Norway, which is part-owned by the UK:

1) A proposal with Dr. Todd Pedersen (AFRL, Albuquerque) entitled "Heater-induced Artificial Ionisation Layers" (HAIL) was awarded 22 running hours on EISCAT (worth $52,800-) and the campaign was successfully executed in July and November 2011. Another similar experiment is expected in 2012.
2) Two third-party EISCAT proposals involving Dr. Paul Bernhardt (NRL, Washington) entitled "Stimulated electromagnetic emissions and ionospheric temperature" and "Stimulated electromagnetic emissions and field-aligned irregularities" were awarded 18 and 24 hours (worth $43,200- and $57,600-), respectively. These will be executed in July 2012.
3) Dr. Paul Bernhardt (NRL, Washington) visited Lancaster University in the UK 21-22 March 2012 for the purpose of coordinating our EISCAT support for the CARE-2 rocket launch from Andoya Rocket Range in Norway, scheduled for August/September 2013.
4) Prof. Wayne Scales (Virginia Tech) was awarded 20 running hours on EISCAT (worth $48,000-) for a proposal entitled "Radiowave heating of mesospheric dusty plasma", which was executed in July 2009. This work was before the period of the EOARD grant. However, following our conversion of the EISCAT Heater into an HF-radar, collaboration will continue with an experiment entitled "PMSE actively charged dust", which has been awarded 24 running runs on EISCAT (worth $57,600-), scheduled for July 2012.
5) I anticipate a new collaboration with Prof. Bill Bristow (Geophysical Institute, Alaska) to support his discovery at HAARP that the growth of ionospheric irregularities depends on plasma temperature. The incoherent scatter radar at the EISCAT facility will be used to observe the electron temperature whilst generating artificial field-aligned irregularities.

Prof. M. J. Kosch
Physics dept.
Lancaster University
Lancaster LA1 4YB
UK
m.kosch@lancaster.ac.uk
+44-(0)1524-510404